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NASA Technical Memorandum 105300

Space Acceleration Measurement System Triaxial Sensor Head Error Budget

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January 1992

NASA

(NASA-TM-105300) SPACE ACCELERATION MEASUREMENT SYSTEM TRIAXIAL SENSOR HEAD ERROR BUDGET (NASA) 28 p CSCL 22B

N92-25134

Unclas
G3/19 0077731

SPACE ACCELERATION MEASUREMENT SYSTEM

TRIAXIAL SENSOR HEAD ERROR BUDGET

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E-6647

SUMMARY

The objective of the Space Acceleration Measurement System (SAMS) is to measure and record the microgravity environment for a given experiment aboard the Space Shuttle. To accomplish this, SAMS uses remote triaxial sensor heads (TSH) that can be mounted directly on or near an experiment. The SAMS project is briefly described as a background for the error budget analysis of the TSH; then the TSH is discussed in more detail with an emphasis on its electrical components. The calibration of the TSH is discussed and the calibration equipment is described. Each TSH will be calibrated before and after flight, and an interpolated model of the two calibration runs will be used as the actual model for the SAMS TSH. The two error sources are discussed both qualitatively and quantitatively, leading to how they were combined to determine the accuracy of the SAMS TSH. The associated error budget for the calibration procedure is discussed.

INTRODUCTION

The Space Acceleration Measurement System (SAMS) has been developed by the NASA Lewis Research Center in support of NASA Headquarters' Microgravity Science and Applications Division program. The primary objective of the SAMS project is to provide an acceleration measurement and recording system that can serve a wide variety of space experiments. The system design takes into consideration requirements for in-space microgravity science and technology experiments that are located in the Space Shuttle middeck, in the cargo bay, or in the Spacelab module.

The main components of SAMS are the remote triaxial sensor heads (TSH) and a main unit that includes a microprocessor-based data acquisition system called the electrical box and an optical storage device that uses optical disks. (Figure 1 shows SAMS in the middeck configuration.) The TSH's use Sundstrand QA2000 accelerometers. These pendulous inertial accelerometers employ a quartz-flexure-suspended proof mass that produces an output current which is proportional to the applied acceleration and independent of the output load. These low-level signals are amplified and filtered by electronics that are located within the TSH. The analog signals are transmitted to the SAMS main unit through sensor head cables that can be as long as 6.1 m (20 ft). In the main unit the signals are further filtered and converted to digital signals, temporarily stored in random-access memory (RAM), and finally transferred to optical disk memory by using optical disk drives.

The SAMS unit begins recording data early in a typical microgravity science mission. Data are recorded continuously throughout the mission until on-orbit science operations are complete. The principal investigators for various space experiments require the time history of the magnitude and frequency of the acceleration environment to which the experiment was exposed. The goals for SAMS are to measure the acceleration magnitude from 1 μg to 0.5 g and the frequency from 0 to 100 Hz.

This report describes the SAMS TSH with Sundstrand QA2000 accelerometers, the errors associated with it, and its overall error budget. The two error sources, measurement system errors and errors inherent to the Sundstrand QA2000 accelerometers, are discussed both qualitatively and quantitatively and then combined by using the root-sum-of-squares method. The resulting single error source is used for the SAMS TSH and its associated data. Calibration data for SAMS Unit-A (the SLS-1 mission) are included and explained in the section "Applying TSH Calibration Models to Acceleration Data."

DESCRIPTION OF TRIAXIAL SENSOR HEAD

Mechanical Description

A SAMS triaxial sensor head is shown assembled and disassembled in figure 2. Each SAMS TSH contains three Sundstrand QA2000-030 accelerometers, one for each orthogonal axis. Accompanying each accelerometer is a preamplifier card (fig. 3) that contains some signal-conditioning circuitry. Each accelerometer has an associated printed circuit interconnect board with terminals soldered to its pins. The terminals on this board serve as the connection points for the wires from the preamplifier cards. The TSH structure is constructed from two pieces of milled 6061-T6511 aluminum: an angle bracket base and a cover. Both pieces are protective treated with Iridite 14-2 per MIL-C-5541C Class 3 and MIL-C-81706 Class 3, Form II Method "B" or "C." The base is flat to 0.002-in. total indicator reading and each axis is orthogonal to within 182 μrad. The TSH weighs approximately 1.12 kg (2.48 lb) and its volume is 11.91 by 10.16 by 6.99 cm (4.69 by 4.00 by 2.75 in.). The accelerometers are mounted to the TSH by means of an adapter ring that is fabricated from 304 stainless steel.

Electrical Description

All electrical interfaces to the TSH are through the sensor head cable, which consists of 24 American wire gauge shielded wires. The power for a TSH comes from a $\pm$15-V dc/dc converter located in the main unit.

The preamplifier cards (schematic shown in fig. 4) can be configured for one of six different low-pass frequencies: 2.5, 5, 10, 25, 50, or 100 Hz. Capacitor C1 is used to roll off the output of each accelerometer at one of the predetermined frequencies. The acceleration output current from each accelerometer, called the scale factor, is converted to a voltage through R1, a 7.5-kΩ

resistor (0.1-percent tolerance). This resistor is sized so that the scale factor is ±10 V/g. This voltage is the input into the programmable-gain operational amplifier. It can be programmed for gains of 1, 10, 100, or 1000. The gain is controlled by the main unit microprocessor, which sends a three-bit word to pins A0, A1, and $\overline{WR}$. The truth table (table I) is used to determine the gain of the programmable-gain operational amplifier. At a gain of 1 the scale factor is ±5V = ±0.5 g, at a gain of 10 the scale factor becomes ±5 V = ±0.05 g, at a gain of 100 the scale factor becomes ±5 V = ±0.005 g, and at a gain of 1000 the scale factor becomes ±5 V = ±0.0005 g. The temperature current signal from the accelerometer is converted to a voltage through R5, a 10-kΩ resistor (1.0-percent tolerance). The temperature of each accelerometer is used during the data reduction process, which is discussed in the section "Applying TSH Calibration Models to Acceleration Data." The last item on the preamplifier board is relay K1. When activated, it disconnects the accelerometer from the circuit and shorts the input to the operational amplifier, thus allowing the dc offset of the system to be measured.

CALIBRATION OF THE SAMS TSH's

Pre- and postflight calibrations will be performed on each SAMS TSH by Sundstrand Data Control, Inc. The calibration procedure is completely automated with the exception of the installation of the TSH into and removal from the test station. The calibration hardware at Sundstrand is shown in figure 5. From the data obtained during these calibrations the fourth-order polynomial coefficients for axis misalignment angles versus temperature, scale factor versus temperature, and bias versus temperature are determined.

During each SAMS flight data will be recorded from the TSH's and stored as raw data. The models (interpolated from the pre- and postflight calibrations) will be applied to the data during postflight data reduction.

The following equipment is used by Sundstrand Data Control, Inc., to calibrate the TSH's:

(1) A precision biaxial station with temperature control capability, namely a Contraves-Goerz Corp. Model 57CD/30H two-axis index table system with a Model 30H-MPACS control system. It can produce a temperature environment of −55 to 95 °C with an accuracy of ±0.05 deg C and a drift of not more than ±0.5 deg C/min. It also consists of a dividing head that can measure and position to 1-arc-sec accuracy about its rotation axis.

(2) A data acquisition system capable of measuring ±1 μV with a full-scale accuracy of 0.001 percent, namely a Fluke 8505A DMM or a Solartron Model 7801.

The axes definitions of the triaxial sensor heads are shown in figure 2(a). The X,Y,Z axes form a right-handed coordinate system with Y and Z being nominally parallel to the TSH mounting surface. The calibration of the TSH will determine the exact orientation of the X,Y,Z coordinate system relative to the TSH mounting surface. The misalignment angles are specified as orthogonal components that are projected on the planes of the reference axes. Positive polarity corresponds to a shift toward the positive axis. Acceleration in the positive direction yields a positive output, giving a positive scale factor.

Data are obtained by taking measurements at 13 temperature settings over the operating range of the Sundstrand QA2000 accelerometers (see fig. 6). A thermal hysteresis curve exists for each accelerometer. During the calibration procedure hysteresis is compensated for by reducing the temperature to −55 °C and allowing the TSH to stabilize at that temperature, thus establishing where the accelerometers are with respect to the hysteresis curves. From this point the TSH is thermally cycled at the 13 temperatures shown in figure 6. While at each temperature the TSH is rotated about two angles, θ_1 and θ_2, on the dividing head (see fig. 7 for angle definitions). The TSH is mounted to the dividing head so that the following axis definitions are true: $X_{TSH} \equiv P$, $Y_{TSH} \equiv Q$, and $Z_{TSH} \equiv R$.

Table II shows the angle positions at which the measurements are taken and which axis is recorded at each position. From these readings the models are developed for the axis misalignments versus temperature, the scale factor (at a gain of 1) versus temperature, and the bias versus temperature.

The high-gain models for the scale factor versus temperature are determined by using the following algorithm: Angles are calculated that will allow the gain of each axis to be increased from 1 to 10, 100, and 1000, respectively, without saturating the output of the TSH. The control system locates the dividing head to each of these angles, and the gain is adjusted appropriately. Measurements are taken at each angle and the scale-factor-versus-temperature models are developed for gains of 10, 100, and 1000. This procedure is repeated for each of the 13 temperature test points.

DESCRIPTION OF ERRORS

Before the errors are described, an important point should be made. All of the error values throughout this document are 3σ numbers.

Two error sources affect the accuracy of the TSH. They are the errors introduced by the measurement system during the calibration procedure and the errors inherent to the Sundstrand QA2000 accelerometers. These error sources are further broken down as shown in figure 8. The errors inherent to the QA2000 accelerometers are categorized into scale factor, bias, and misalignment errors. The scale factor is the current output produced by the accelerometer, which is proportional to the input acceleration, the bias is the output of the accelerometer with zero acceleration input, and the angle misalignment is the amount each axis is misaligned with respect to the remaining two axes. The error magnitudes are worst-case numbers; Sundstrand guarantees that no error magnitude will be greater than the quoted values. All three of these errors change as a function of temperature. The measurement system errors consist of the uncertainties of the data measured (temperature, voltage, and current), dividing head errors (including leveling, nonrepeatability, nonorthogonality, and fixture warping due to temperature changes during the calibration procedure), and system noise.

All of these specific errors are combined by using the root-sum-of-squares method into seven distinct errors for each accelerometer axis (21 per TSH). Each TSH axis contains the following errors: four scale-factor-versus-temperature errors (one at each gain setting), a bias-versus-temperature error, and two axis-misalignment-versus-temperature errors. A fourth-order polynomial model is then developed for each error to compensate for temperature changes that affect the TSH performance. These models are in the form of coefficients as part of the calibration data sheets (fig. 9) supplied by Sundstrand. For each axis of the TSH the seven models are as follows: B0 to B4 for bias, C0 to C4 for scale factor (gain = 1), D0 to D4 and E0 to E4 for axis misalignment angles, F0 to F4 for scale factor (gain = 10), G0 to G4 for scale factor (gain = 100), and H0 to H4 for scale factor (gain = 1000).

The inherent errors of the Sundstrand QA2000 accelerometers discussed in this document are the error values after the calibration models have been applied to the data.

ERROR BUDGET FOR SAMS TSH

The error budget is given here for the Sundstrand QA2000 accelerometers only. Measurement system errors do not originate from the TSH but instead originate from the equipment used during the calibration procedure. Table III shows the measurement system errors, including the error magnitude and where the error is applicable. Then the errors are combined by using the root-sum-of-squares (RSS) method.

Absolute errors in input axis misalignment differ from the axis misalignment errors in table III as follows: The axis misalignment errors in table III are due to warping of the TSH over temperature, whereas the absolute errors in input axis misalignment are due to the non-orthogonality of the dividing head, the inability to accurately level the dividing head, and the fixture accuracy. The axis misalignment errors inherent to the Sundstrand QA2000 accelerometers are also included in the absolute misalignment errors shown in table IV.

For a single accelerometer the misalignment angles are expressed in terms of hinge axis and pendulous axis misalignment. When the accelerometers are configured in a TSH, the misalignment angles are expressed with respect to each orthogonal axis of the TSH.

The errors inherent to the Sundstrand QA2000-030 accelerometers are given as scale factor errors in table V and bias errors in table VI. All of the individual errors are combined by using the RSS method.

The scale factor and bias stability terms are the magnitude of uncertainty at a given temperature. Thus, at any given temperature the scale factor or bias of the QA2000 accelerometer is known to within this amount.

RESULTS

The composite error budget for the SAMS triaxial sensor head consists of 21 fourth-order polynomial models, one for each of the 21 different errors (seven for each TSH axis). Associated with each TSH axis is the set of models for each error shown in table VII and models for two of the six errors shown in table VIII. Which two errors are applicable to a particular axis from table VIII is determined by the components of each orthogonal axis. These errors are a composite of errors inherent to the accelerometers and errors resulting from the calibration procedure measurement system. They are combined by using the RSS method.

The composite input axis misalignment errors combine errors from two sources: measurement system errors and absolute errors in δ_{jk}. The total input axis misalignment errors can be obtained by using the RSS method to combine the errors. The results are given in table VIII.

With the models applied to the data the accuracy of the TSH's is shown in table IX. The accuracy values in table IX are a result of both scale factor and bias errors. The scale factor errors are given as percentage errors of the measured acceleration value, and the bias errors are in the form of microgravities. Note that all of the accuracy values given in table IX are known to within the RSS values of angle misalignments shown in table VIII.

At a gain of 1 the 0.03-percent scale factor error (150 μg) is the major contributor to the total full-scale error. At gains of 10, 100, and 1000 the major error contribution is a result of the ± 98.6-μg bias error. At a gain of 10 the 0.03-percent maximum scale factor error at full scale is 15 μg, at a gain of 100 the 0.05-percent maximum scale factor error is 2.5 μg, and at a gain of 1000 the 0.42-percent maximum scale factor error is 2.1 μg.

APPLYING TSH CALIBRATION MODELS TO ACCELERATION DATA

The postmission calibration data sheets for one of the SLS-1 mission TSH's are included here (fig. 9) as an example of the models that Sundstrand supplies as a result of the calibration procedure. The data from the 13 temperature cycles are included as part of the calibration data package from Sundstrand but are not discussed here. For each TSH axis fourth-order polynomials are given for bias (B0 to B4), scale factor (C0 to C4), and axis misalignments (D0 to D4 and E0 to E4) versus temperature. Then the high-gain scale factor models versus temperature are given (F0 to F4 for a gain of 10, G0 to G4 for a gain of 100, and H0 to H4 for a gain of 1000).

The following method, including the application of the fourth-order polynomial models, is used to characterize the acceleration environment to the accuracy described in table IX for each TSH axis:

(1) Prior to recording data SAMS obtains a dc offset value of each acceleration channel by activating the relays in the TSH and measuring the voltage. SAMS stores this value and during data compensation subtracts it from each data point.

(2) Binary data, temperature ($COUNTS_{TEMP}$) and acceleration ($COUNTS_{ACCEL}$), are recorded by SAMS. The first step in postflight data processing is to convert from binary to decimal. $COUNTS_{TEMP}$ results in a decimal number, called T_{cts}, and is always positive. $COUNTS_{ACCEL}$ is in 2's complement format and results in a decimal number, called A_{cts}, and is in the range −32 767 to 32 768.

(3) In order to compensate for changes due to temperature, the recorded temperature from the accelerometers is normalized to 20 °C. This normalized temperature factor A_I is measured in microamperes and is derived from the temperature counts T_{cts} by the following equation:

$$A_I = \left(\frac{\dfrac{T_{cts} \times 5}{2^{16}}}{10^4 \times 10^6} \right) - 293$$

(4) The accelerometer bias term (BIAS), in micro-g's, is calculated by using the "B" set of coefficients along with the A_I term as follows:

$$BIAS = B_0 + B_1(A_I) + B_2(A_I)^2 + B_3(A_I)^3 + B_4(A_I)^4$$

(5) The gain setting for any particular acceleration data point is indicated in the SAMS recorded data by a two-bit data word. This indicates whether the gain was 1, 10, 100, or 1000 for that data point. The scale factor term SF_{XX}, in volts per g, is calculated by using the scale factor coefficients that are appropriate for the gain setting, along with the A_I term, as follows:

For gain = 1

$$SF_{00} = C_0 + C_1(A_I) + C_2(A_I)^2 + C_3(A_I)^3 + C_4(A_I)^4$$

For gain = 10

$$SF_{01} = F_0 + F_1(A_I) + F_2(A_I)^2 + F_3(A_I)^3 + F_4(A_I)^4$$

For gain = 100

$$SF_{10} = G_0 + G_1(A_I) + G_2(A_I)^2 + G_3(A_I)^3 + G_4(A_I)^4$$

For gain = 1000

$$SF_{11} = H_0 + H_1(A_I) + H_2(A_I)^2 + H_3(A_I)^3 + H_4(A_I)^4$$

(6) The acceleration in milli-g's is calculated by using A_{cts}, BIAS, and the appropriate scale factor term as follows:

$$\text{ACCELERATION} = \left(\frac{A_{cts} \times 10^4}{2^{16} \times SF_{XX}} \right) - \frac{\text{BIAS}}{10^3}$$

This acceleration value has two components of cross-axis acceleration from the two TSH perpendicular axes. This is a result of the axis misalignment of the accelerometers and the axis shift due to temperature change. The axis misalignment is measured in microradians and is calculated as follows:

$$DELTA_{**} = D_0 + D_1(A_I) + D_2(A_I)^2 + D_3(A_I)^3 + D_4(A_I)^4$$

$$DELTA_{**} = E_0 + E_1(A_I) + E_2(A_I)^2 + E_3(A_I)^3 + E_4(A_I)^4$$

where $DELTA_{**}$ is the axis misalignment angle in the direction of one of the two perpendicular axes of the TSH.

(7) In order to obtain the true acceleration (T_X, T_Y, or T_Z) for each TSH axis, the axis misalignment terms $DELTA_{**}$ shown in the preceding equations (simplified as either XY, XZ, YX, YZ, ZX, or ZY), must be applied to the ACCELERATION terms shown previously (simplified as either A_X, A_Y, or A_Z) to compensate for any cross-axis accelerations. The following equations are used to obtain the true acceleration data for each TSH axis:

$$T_X = A_X[\cos(XY)\cos(XZ)] - A_Y \sin(XY) - A_Z \sin(XZ)$$

$$T_Y = A_Y[\cos(YX)\cos(YZ)] - A_X \sin(YX) - A_Z \sin(YZ)$$

$$T_Z = A_Z[\cos(ZX)\cos(ZY)] - A_X \sin(ZX) - A_Y \sin(ZY)$$

Examining the data supplied by Sundstrand Data Control, Inc., shows that the misalignment angles are small. Thus, by using the relationships

$$\cos(\text{small angle}) = 1$$

and

$$\sin(\text{small angle}) = \text{small angle}$$

the TSH true-axis acceleration can be calculated by using the following simplified equations:

$$T_X = A_X - (A_Y XY) - (A_Z XZ)$$

$$T_Y = A_Y - (A_X YX) - (A_Z YZ)$$

$$T_Z = A_Z - (A_X ZX) - (A_Y ZY)$$

These true axis acceleration data are supplied to anyone interested in the acceleration environment characterized by SAMS. A plot of uncompensated SAMS data from the SLS-1 mission is shown in figure 10(a). All of the applicable models discussed herein were applied to the data, and the result is shown in figure 10(b).

CONCLUDING REMARKS

A brief description of the SAMS project was given as a background for the error budget analysis of the TSH. Next the TSH was discussed in more detail with an emphasis on the TSH electrical components. Then the calibration of the TSH was discussed, and the calibration equipment was described. Each TSH will be calibrated before and after flight, and an interpolated model of the two calibration runs will be used as the actual model for the SAMS TSH. The two error sources were discussed both qualitatively and quantitatively, leading to how they were combined to determine the accuracy of the SAMS TSH.

APPENDIX A

SYMBOLS

A_{cts}	decimal acceleration data
A_I	normalized temperature factor
B0 - B4	bias model coefficients
C0 - C4	scale factor coefficients at gain of 1
$COUNTS_{ACCEL}$	binary acceleration data
$COUNTS_{TEMP}$	binary temperature data
$DELTA_{**}$	axis misalignment angle
D0 - D4	angle misalignment coefficients

E0 - E4	angle misalignment coefficients
F0 - F4	scale factor coefficients at gain of 10
G0 - G4	scale factor coefficients at gain of 100
g	normal acceleration due to Earth's gravity (9.81 m/s^2)
H0 - H4	scale factor coefficients at gain of 1000
SF_{XX}	scale factor, XX denotes gain setting
T_{cts}	decimal temperature data
T_X, T_Y, T_Z	true axis acceleration
δ	axis misalignment angle
μ	micro (10^{-6})
θ_1, θ_2	angle of rotation on dividing head
σ	standard deviation

APPENDIX B

ACRONYMS

DMM	digital multimeter
NASA	National Aeronautics and Space Administration
ppm	parts per million
RAM	random-access memory
rms	root mean square
RSS	root sum of squares
SAMS	Space Acceleration Measurement System
SLS–1	first Space Life Science Mission
TSH	triaxial sensor head

TABLE I.—TRUTH TABLE FOR TSH PREAMPLIFIER CARD

$\overline{WR}$	A1	A0	Gain
1	X	X	Maintains previous gain
0	0	0	1
0	0	1	10
0	1	0	100
0	1	1	1000

TABLE II.—POSITIONS FOR DETERMINING AXIS MISALIGNMENT, SCALE FACTOR (GAIN = 1), AND BIAS MODELS

Position	Dividing head angles, deg		Measure		
	θ_1	θ_2	X	Y	Z
1	0	270	*	*	*
2	30			*	*
3	60			*	*
4	90		*	*	*
5	120			*	*
6	150			*	*
7	180		*	*	*
8	210			*	*
9	240			*	*
10	270		*	*	*
11	300			*	*
12	330			*	*
13	0	330	*	*	
14		300	*	*	
15		270	*	*	*
16		240	*	*	
17		210	*	*	
18		180	*	*	*
19		150	*	*	
20		120	*	*	
21		90	*	*	*
22		60	*	*	
23		30	*	*	
24		0	*	*	*
25	90	0	*	*	*
26		30	*		*
27		60	*		*
28		90	*	*	*
29		120	*		*
30		150	*		*
31		180	*	*	*
32		210	*		*
33		240	*		*
34		270	*	*	*
35		300	*		*
36		330	*		*

TABLE III.—MEASUREMENT SYSTEM ERRORS

Error source	Magnitude	Bias, μg	Scale factor,[a] ppm				Input axis misalignment nonrepeatability,[b] μrad		
			G = 1	G = 10	G = 100	G = 1000	δ_{XY}, δ_{XZ}	δ_{YX}, δ_{ZX}	δ_{YZ}, δ_{ZY}
Voltmeter bias	8 μV	1	---	---	----	----	----	----	----
Voltmeter scaling	10 ppm	--	10	10	10	10	----	----	----
Slip rings, connections, etc.	5 μV	1	1	1	1	1	1	1	1
Sensor temperature drift (compensated)	1 °C	2	3	7	7	7	2	2	2
AD590 measurement	0.03 °C	1	3	10	10	10	1	1	1
Mechanical and electrical noise (filtered)	3 μg	1	<1	42	420	4200	<1	<1	<1
K_2, K_{IP}[c]	16 $\mu g/g^2$	4	2	2	2	2	<1	1	1
Dividing head θ_1 runout	2 μrad	--	---	---	---	----	2	2	2
Fixture warping	5 μrad	--	---	---	---	----	5	5	----
θ_1 dividing head nonrepeatability	2 μrad	--	---	---	---	----	----	----	2
RSS		5.0	11.2	44	420	4200	6.2	6.2	3.6

[a]The scale factor errors do not increase by a decade as the gain increases by a decade because at a gain of 1 more data points are measured and the errors are averaged out.
[b]These errors relate to changes in misalignment over temperature. The additional errors due to absolute alignment (zero-order terms of the model) are given in table IV.
[c]Terms in the accelerometer equation.

TABLE IV.—ABSOLUTE AXIS MISALIGNMENT ERRORS IN δ_{jk}

Error source	Magnitude, μrad	Input axis misalignment, μrad		
		δ_{XY}, δ_{XZ}	δ_{YX}, δ_{ZX}	δ_{YZ}, δ_{ZY}
Nonorthogonality of dividing head	10	10	10	---
Spirit level accuracy	50	---	---	50
Fixture accuracy	50	---	---	50
RSS		10	10	70.7

TABLE V.—SCALE FACTOR ERROR BUDGET FOR SUNDSTRAND QA2000-030 ACCELEROMETERS

Error source	Limit, ppm
150 g shock + 5 g rms[a]	180
Scale factor thermal hysteresis (0 to peak)[b]	100
Scale factor nominal instability[c]	150
Scale factor thermal coefficient instability[c]	150
Scale factor model error[d]	40
Temperature error[e]	20
RSS scale factor stability	300

[a]Effect of a single exposure.
[b]Worst case, −55 to 95 °C.
[c]Environmental effects acting over 1 year.
[d]Residuals from model.
[e]Effect of thermal drift during temperature test.

TABLE VI.—BIAS ERROR BUDGET FOR SUNDSTRAND QA2000-030 ACCELEROMETERS

Error source	Limit, μg
150 g shock + 5 g rms[a]	50
Bias thermal hysteresis (0 to peak)[b]	50
Bias instability[c]	60
Bias thermal coefficient instability[c]	25
Bias model error[d]	20
Bias measurement error[e]	7
Temperature error[f]	5
RSS bias stability	98.5

[a]Effect of a single exposure.
[b]Worst case, −55 to 95 °C.
[c]Environmental effects acting over 1 year.
[d]Residuals from model.
[e]Includes measurement error but not temperature hysteresis.
[f]Effect of thermal drift during temperature test.

TABLE VII.—RSS ERROR BUDGET FOR SCALE FACTOR AND BIAS FOR SAMS TSH

[The RSS stability values are valid for 1 year.]

Error source	Bias, μg	Gain			
		1	10	100	1000
		Scale factor, ppm			
Measurement system (from table III)	5.0	11.2	44	420	4200
Errors inherent to QA2000-030 accelerometer (from table VI)	98.5	300	300	300	300
RSS stability	98.6	300.2	303	516	4210

TABLE VIII.—ABSOLUTE ERRORS IN δ_{jk}

Error source	Input axis measurement, μrad		
	δ_{XY}, δ_{XZ}	δ_{YX}, δ_{ZX}	δ_{YZ}, δ_{ZY}
Measurement system (from table III)	6.2	6.2	3.6
Absolute axis measurement (from table IV)	10	10	70.7
RSS	11.8	11.8	70.8

TABLE IX.—ACCURACY OF SAMS TSH USING SUNDSTRAND QA2000-030 ACCELEROMETERS

Gain	Accuracy, percent ±98.6 μg
1	0.03
10	.03
100	.05
1000	.42

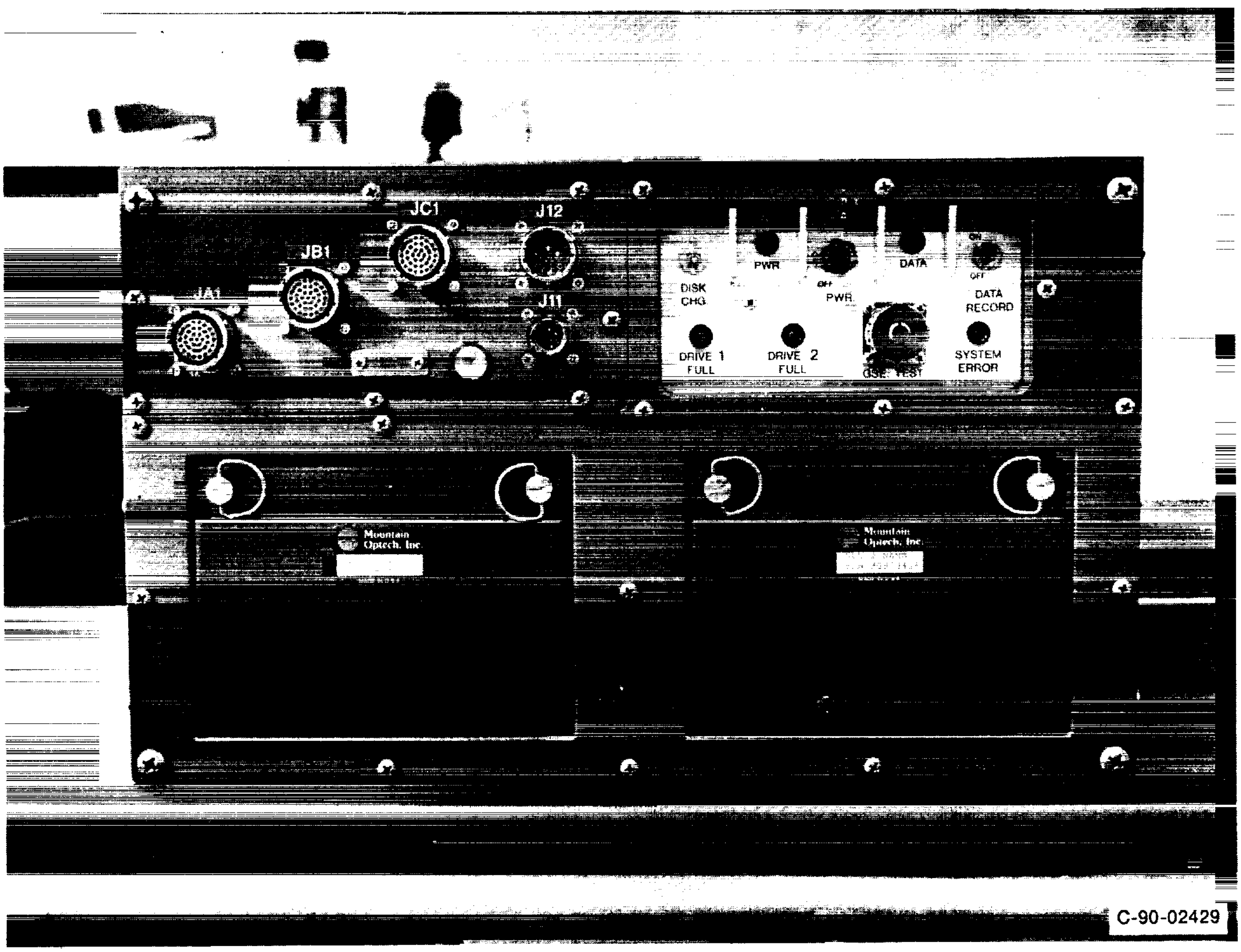

Figure 1.—SAMS in middeck configuration (front panel).

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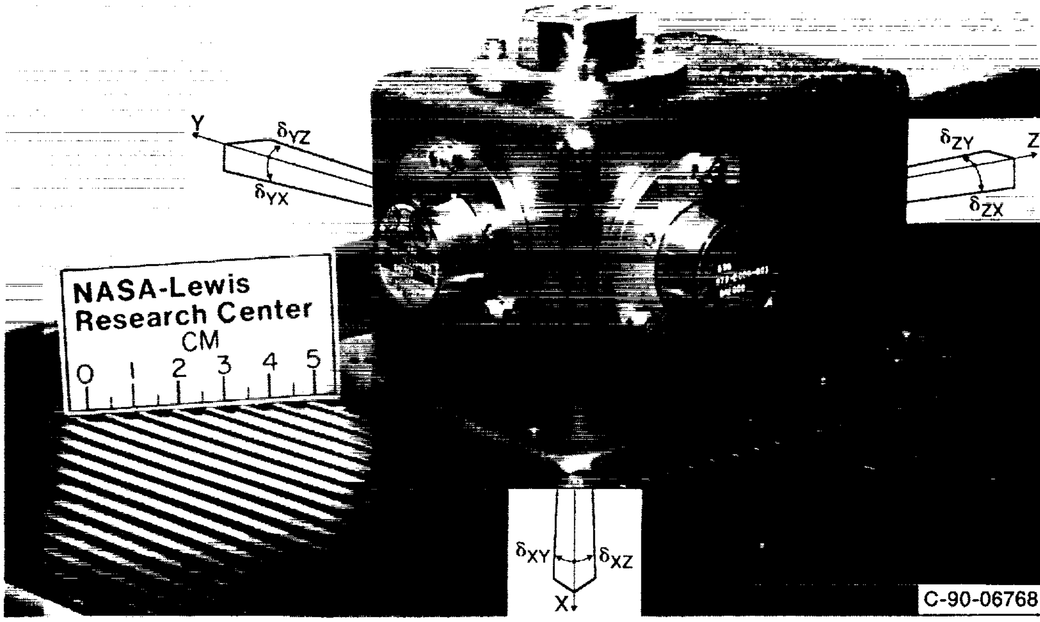
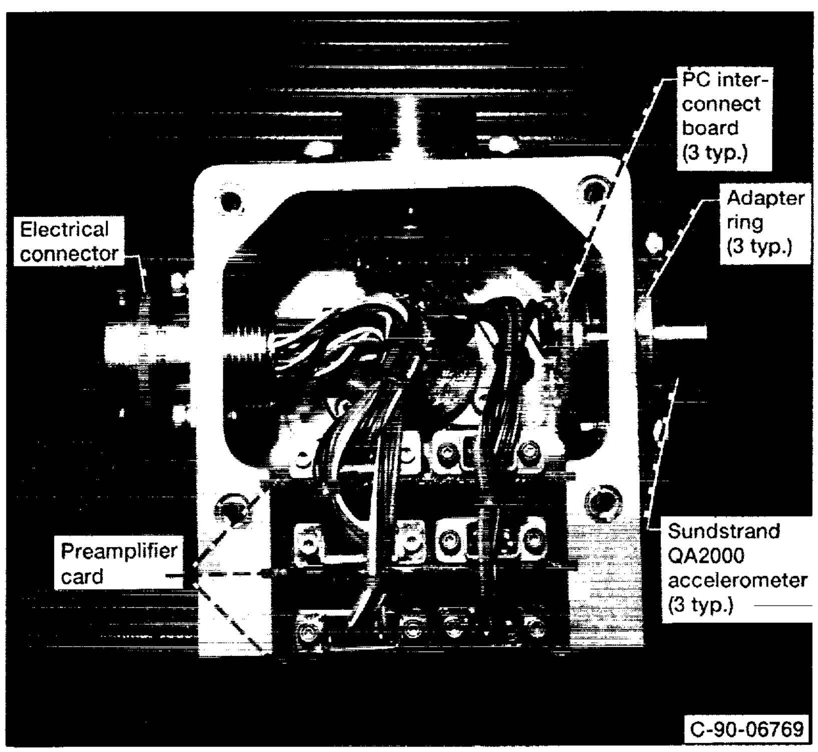
BLACK AND WHITE PHOTOGRAPH



(a) External view with axes definitions.



(b) Internal view.

Figure 2.—SAMS triaxial sensor head.

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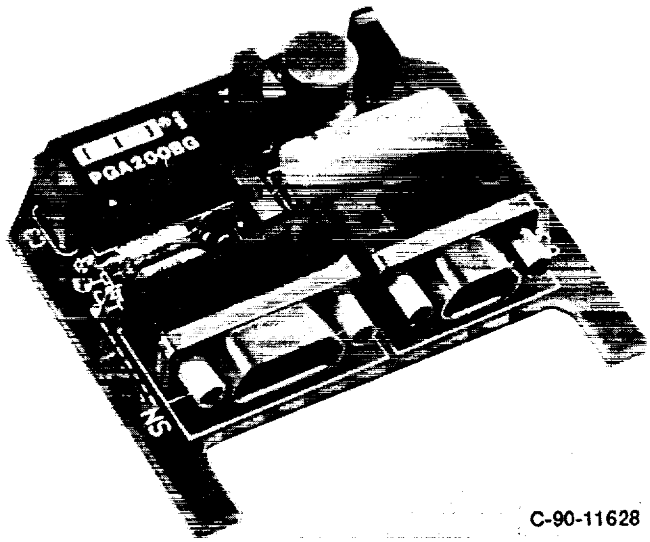

Figure 3.—Preamplifier card for Sundstrand QA2000-030 accelerometers.

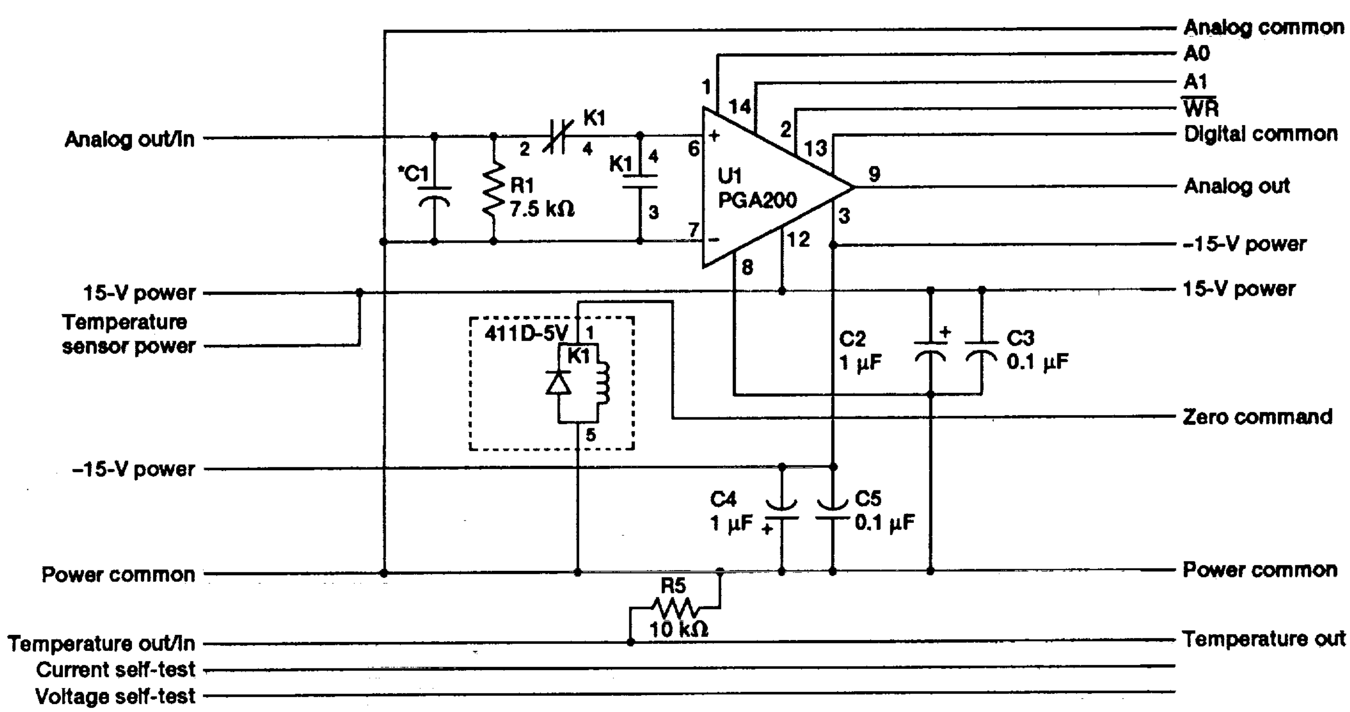

Figure 4.—Schematic of preamplifier card (three per TSH).

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ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

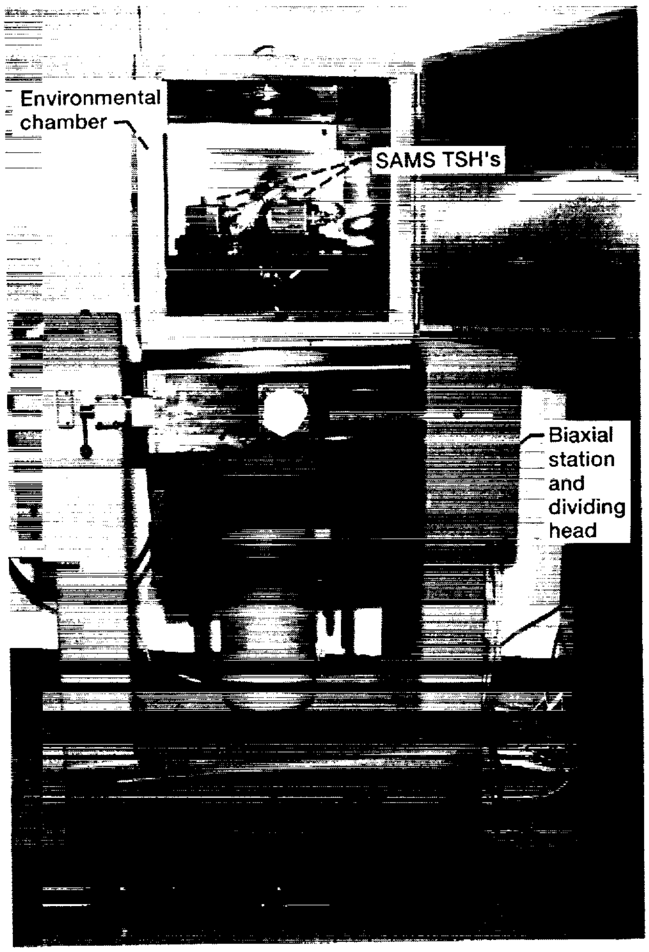


Figure 5.—Calibration hardware at Sundstrand Data Control, Inc.

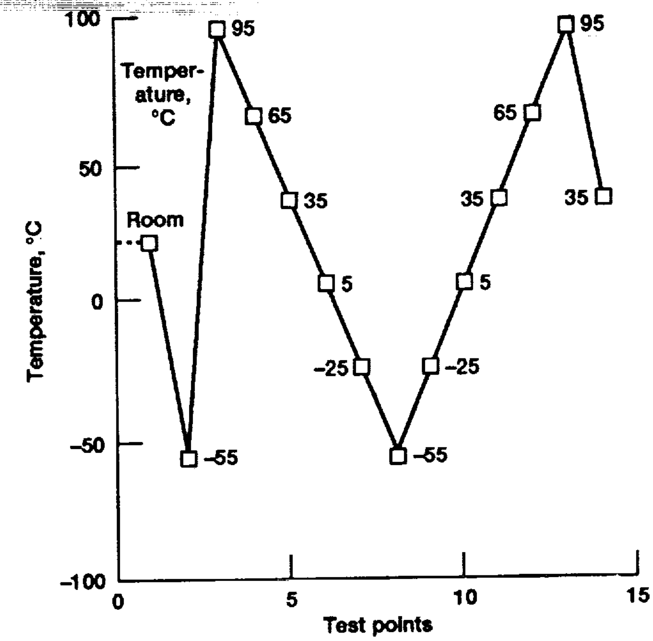


Figure 6.—Calibration temperature test points.

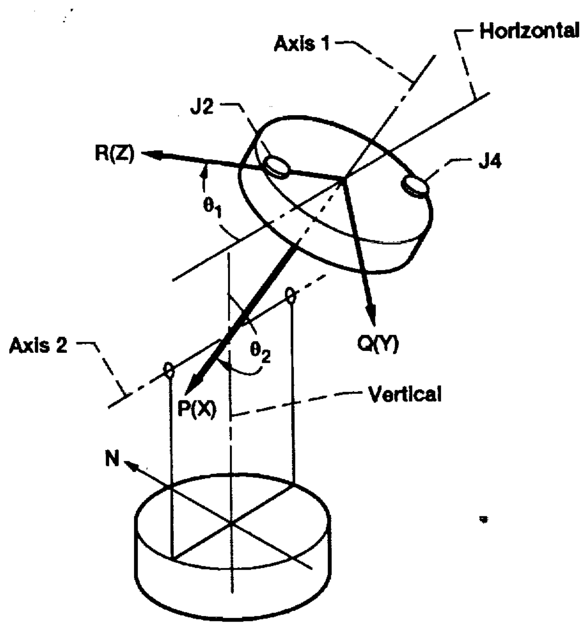


Figure 7.—Dividing head angle definitions.

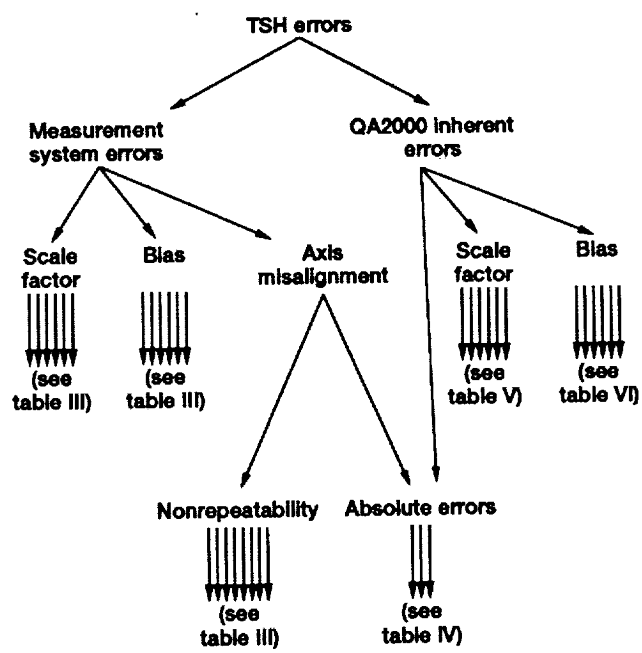


Figure 8.—Tree diagram of error types.

DWG NO. | SH | REV

SAMS CALIBRATION TEST DATA
X AXIS MODEL DATA SHEET

P/N 2 S/N 821 DATE 13-Aug-91 LOCAL g - 980.708 cm/sec²

TEMPERATURE (°C)		BIAS (µg)	SCALE FACTOR (V/g)	TEMP SENSOR (µA)
T 1	93.35	-2782	9.61526	369.485
T 2	63.93	-2860	9.57637	339.455
T 3	33.70	-2963	9.54262	309.198
T 4	3.85	-3017	9.51450	279.432
T 5	-26.18	-3016	9.49268	249.834
T 6	-56.80	-2972	9.47932	219.802
T 7	-26.13	-3002	9.49343	249.914
T 8	3.67	-2984	9.51608	279.355
T 9	34.15	-2936	9.54377	308.879
T10	63.91	-2852	9.57644	338.545
T11	93.55	-2781	9.61408	368.740
T12	33.39	-2960	9.54127	307.867

		COEFFICIENTS (@293µA)		COEFFICIENTS (@293µA)		COEFFICIENTS (@20°C)
CONSTANT:	B0=	-2985	C0 =	9.527293	A0 =	295.175
1st ORDER:	B1=	1.81	C1 =	939.02E-06	A1 =	0.99203
2nd ORDER:	B2=	29.3E-03	C2 =	2969.9E-09		
3rd ORDER:	B3=	-99E-06	C3 =	-7678E-12		
4th ORDER:	B4=	-177E-08	C4 =	6265E-14		

TEMPERATURE (°C)		RESIDUALS (µg)	RESIDUALS (ppm)	RESIDUALS (µA)
T 1	93.35	-1	7	0.59
T 2	63.93	-4	-50	0.36
T 3	33.70	-14	-67	0.40
T 4	3.85	-12	-65	0.23
T 5	-26.18	-9	-47	0.09
T 6	-56.80	1	4	-0.23
T 7	-26.13	5	27	0.12
T 8	3.67	20	108	0.33
T 9	34.15	14	88	-0.37
T10	63.91	8	70	-0.53
T11	93.55	0	-10	-0.36
T12	33.39	-8	-64	-0.62
SHIFT:		6	2	-1.02
HYSTERESIS(p-p):				
TEMP=	63.92	6	118	0.02
TEMP=	33.93	24	154	-0.09
TEMP=	3.76	30	172	0.55
TEMP=	-26.15	12	74	0.25

SDC F-91

050-2283-001 REV NEW

SIZE	FSCM NO.	DWG NO.	REV
A	97896		
SCALE: NONE		SHEET	

SDCF-1475

Figure 9.—Sundstrand data sheets.

DWG NO. | SH | REV

SAMS CALIBRATION TEST DATA
X AXIS δ MODEL DATA SHEET

P/N 2 S/N 821 DATE 13-Aug-91 LOCAL g - 980.708 cm/sec²

	TEMPERATURE (°C)	δXY (μrad)	δXZ (μrad)	TEMP SENSOR (μA)
T 1	93.35	-158	1023	369.485
T 2	63.93	-198	1017	339.455
T 3	33.70	-218	1002	309.198
T 4	3.85	-233	1010	279.432
T 5	-26.18	-230	1010	249.834
T 6	-56.80	-219	1010	219.802
T 7	-26.13	-224	1028	249.914
T 8	3.67	-179	1060	279.355
T 9	34.15	-167	1070	308.879
T10	63.91	-144	1052	338.545
T11	93.55	-136	1026	368.740
T12	33.39	-192	1019	307.867

		COEFFICIENTS (@293μA)		COEFFICIENTS (@293μA)		COEFFICIENTS (@20°C)
CONSTANT:	D0=	-200	E0 =	1032	A0 =	295.175
1st ORDER:	D1=	0.65	E1 =	0.13	A1 =	0.99203
2nd ORDER:	D2=	-1.3E-03	E2 =	-3.1E-03		
3rd ORDER:	D3=	-33E-06	E3 =	-2E-06		
4th ORDER:	D4=	75E-08	E4 =	4E-08		

	TEMPERATURE (°C)	RESIDUALS (μrad)	RESIDUALS (μrad)	RESIDUALS (μA)
T 1	93.35	-11	-2	0.59
T 2	63.93	-26	-15	0.36
T 3	33.70	-28	-31	0.40
T 4	3.85	-24	-20	0.23
T 5	-26.18	-5	-12	0.09
T 6	-56.80	1	1	-0.23
T 7	-26.13	2	7	0.12
T 8	3.67	30	30	0.33
T 9	34.15	23	36	-0.37
T10	63.91	28	20	-0.53
T11	93.55	11	1	-0.36
T12	33.39	-1	-15	-0.62
SHIFT:		27	16	-1.02
HYSTERESIS(p-p):				
TEMP=	63.92	31	21	0.02
TEMP=	33.93	33	57	-0.09
TEMP=	3.76	43	43	0.55
TEMP=	-26.15	0	15	0.25

SDC 91

050-2283-001 REV NEW

SIZE A	FSCM NO. 97896	DWG NO.	REV
SCALE: NONE		SHEET	

SDCF-1475

Figure 9.—Continued.

DWG NO.	SH	REV

SAMS CALIBRATION TEST DATA
Y AXIS MODEL DATA SHEET

P/N 2 S/N 821 DATE 13-Aug-91 LOCAL g - 980.708 cm/sec²

TEMPERATURE (°C)		BIAS (µg)	SCALE FACTOR (V/g)	TEMP SENSOR (µA)
T 1	93.13	680	10.43232	370.072
T 2	63.59	989	10.38549	339.366
T 3	33.39	1007	10.34410	308.773
T 4	3.63	1016	10.30858	278.756
T 5	-26.43	1080	10.28027	248.765
T 6	-56.95	1179	10.26197	218.767
T 7	-26.41	1097	10.28160	248.904
T 8	3.59	1058	10.31172	279.213
T 9	34.16	1045	10.34630	308.854
T10	63.78	1005	10.38609	338.718
T11	93.51	-279	10.43114	369.209
T12	33.58	1005	10.34297	307.859

		COEFFICIENTS (@293µA)		COEFFICIENTS (@293µA)		COEFFICIENTS (@20°C)
CONSTANT:	B0=	1020	C0 =	10.325714	A0 =	294.958
1st ORDER:	B1=	1.12	C1 =	1174.37E-06	A1 =	1.00269
2nd ORDER:	B2=	41.2E-03	C2 =	3104.8E-09		
3rd ORDER:	B3=	-1253E-06	C3 =	-10215E-12		
4th ORDER:	B4=	-1643E-08	C4 =	6913E-14		

TEMPERATURE (°C)		RESIDUALS (µg)	RESIDUALS (ppm)	RESIDUALS (µA)
T 1	93.13	483	-11	0.75
T 2	63.59	29	-63	0.33
T 3	33.39	-35	-85	0.35
T 4	3.63	1	-104	0.16
T 5	-26.43	-17	-70	-0.05
T 6	-56.95	2	5	-0.18
T 7	-26.41	1	48	0.07
T 8	3.59	43	153	0.66
T 9	34.16	3	118	-0.34
T10	63.78	39	84	-0.51
T11	93.51	-514	8	-0.50
T12	33.58	-35	-83	-0.75
SHIFT:		-0	2	-1.10

HYSTERESIS(p-p):

TEMP= 63.68	10	145	0.14
TEMP= 33.77	38	201	0.04
TEMP= 3.61	43	256	0.99
TEMP=-26.42	18	117	0.36

SDC 91

SIZE	FSCM NO.	DWG NO.	REV
A	97896		
SCALE: NONE		SHEET	

050-2283-001 REV NEW

SDCF-1475

Figure 9.—Continued.

DWG NO. | SH | REV

SAMS CALIBRATION TEST DATA
Y AXIS δ MODEL DATA SHEET

P/N 2 S/N 821 DATE 13-Aug-91 LOCAL g - 980.708 cm/sec²

TEMPERATURE (°C)		δYX (µrad)	δYZ (µrad)	TEMP SENSOR (µA)
T 1	93.13	211	547	370.072
T 2	63.59	225	549	339.366
T 3	33.39	292	543	308.773
T 4	3.63	332	540	278.756
T 5	-26.43	334	524	248.765
T 6	-56.95	318	521	218.767
T 7	-26.41	303	544	248.904
T 8	3.59	254	544	279.213
T 9	34.16	209	569	308.854
T10	63.78	156	591	338.718
T11	93.51	291	633	369.209
T12	33.58	234	646	307.859

		COEFFICIENTS (@293µA)		COEFFICIENTS (@293µA)		COEFFICIENTS (@20°C)
CONSTANT:	D0=	273	E0 =	568	A0 =	294.958
1st ORDER:	D1=	-1.86	E1 =	0.68	A1 =	1.00269
2nd ORDER:	D2=	-13.5E-03	E2 =	-11.1E-03		
3rd ORDER:	D3=	240E-06	E3 =	-48E-06		
4th ORDER:	D4=	262E-08	E4 =	157E-08		

TEMPERATURE (°C)		RESIDUALS (µrad)	RESIDUALS (µrad)	RESIDUALS (µA)
T 1	93.13	-41	-41	0.75
T 2	63.59	31	-30	0.33
T 3	33.39	50	-33	0.35
T 4	3.63	36	-16	0.16
T 5	-26.43	16	-3	-0.05
T 6	-56.95	-0	-3	-0.18
T 7	-26.41	-15	17	0.07
T 8	3.59	-41	-14	0.66
T 9	34.16	-32	-7	-0.34
T10	63.78	-39	13	-0.51
T11	93.51	43	46	-0.50
T12	33.58	-9	70	-0.75
SHIFT:		-60	103	-1.10
HYSTERESIS(p-p):				
TEMP=	63.68	-17	-49	0.14
TEMP=	33.77	-43	-43	0.04
TEMP=	3.61	-51	-43	0.99
TEMP=	-26.42	-18	-3	0.36

SDC 91

SIZE A | FSCM NO. 97896 | DWG NO. | REV

SCALE: NONE | SHEET

050-2283-001 REV NEW

SDCF-1475

Figure 9.—Continued.

DWG NO. | SH | REV

SAMS CALIBRATION TEST DATA
Z AXIS MODEL DATA SHEET

P/N 2 S/N 821 DATE 13-Aug-91 LOCAL g - 980.708 cm/sec²

TEMPERATURE (°C)		BIAS (μg)	SCALE FACTOR (V/g)	TEMP SENSOR (μA)
T 1	93.29	-727	9.72804	370.298
T 2	63.78	-826	9.69242	340.040
T 3	33.58	-993	9.66094	309.473
T 4	3.78	-1086	9.63511	279.425
T 5	-26.27	-1152	9.61575	249.691
T 6	-56.86	-1194	9.60585	219.685
T 7	-26.25	-1156	9.61668	249.775
T 8	3.67	-1093	9.63690	279.491
T 9	34.16	-1007	9.66150	309.005
T10	63.85	-849	9.69176	338.929
T11	93.56	-727	9.72673	369.273
T12	33.48	-1005	9.65938	307.869

		COEFFICIENTS (@293μA)		COEFFICIENTS (@293μA)		COEFFICIENTS (@20°C)
CONSTANT:	B0=	-1059	C0 =	9.646668	A0 =	295.318
1st ORDER:	B1=	3.48	C1 =	851.13E-06	A1 =	0.99757
2nd ORDER:	B2=	36.0E-03	C2 =	2943.6E-09		
3rd ORDER:	B3=	-60E-06	C3 =	-9520E-12		
4th ORDER:	B4=	-342E-08	C4 =	6739E-14		

TEMPERATURE (°C)		RESIDUALS (μg)	RESIDUALS (ppm)	RESIDUALS (μA)
T 1	93.29	-2	-2	0.72
T 2	63.78	13	-14	0.63
T 3	33.58	-0	-53	0.56
T 4	3.78	13	-60	0.23
T 5	-26.27	-3	-61	0.07
T 6	-56.86	2	6	-0.23
T 7	-26.25	-7	31	0.13
T 8	3.67	7	122	0.41
T 9	34.16	-13	51	-0.48
T10	63.85	-4	43	-0.54
T11	93.56	0	-4	-0.58
T12	33.48	-6	-59	-0.73
SHIFT:		-5	-6	-1.49
HYSTERESIS(p-p):				
TEMP=	63.81	-13	61	0.15
TEMP=	33.87	-9	108	-0.05
TEMP=	3.72	-4	184	0.84
TEMP=	-26.26	-3	94	0.40

SDC FI 81

050-2283-001 REV NEW

SIZE	FSCM NO.	DWG NO.	REV
A	97896		
SCALE: NONE		SHEET	

SDCF-1475

Figure 9.—Continued.

DWG NO.	SH	REV

SAMS CALIBRATION TEST DATA
Z AXIS δ MODEL DATA SHEET

P/N 2 S/N 821 DATE 13-Aug-91 LOCAL g - 980.708 cm/sec²

	TEMPERATURE (°C)	δZX (μrad)	δZY (μrad)	TEMP SENSOR (μA)
T 1	93.29	-799	589	370.298
T 2	63.78	-825	594	340.040
T 3	33.58	-833	635	309.473
T 4	3.78	-815	651	279.425
T 5	-26.27	-795	677	249.691
T 6	-56.86	-752	696	219.685
T 7	-26.25	-813	649	249.775
T 8	3.67	-821	617	279.491
T 9	34.16	-848	574	309.005
T10	63.85	-854	534	338.929
T11	93.56	-847	503	369.273
T12	33.48	-883	535	307.869

		COEFFICIENTS (@293μA)		COEFFICIENTS (@293μA)		COEFFICIENTS (@20°C)
CONSTANT:	D0=	-840	E0 =	606	A0 =	295.318
1st ORDER:	D1=	-0.58	E1 =	-1.35	A1 =	0.99757
2nd ORDER:	D2=	8.8E-03	E2 =	4.7E-03		
3rd ORDER:	D3=	20E-06	E3 =	65E-06		
4th ORDER:	D4=	6E-08	E4 =	-35E-08		

	TEMPERATURE (°C)	RESIDUALS (μrad)	RESIDUALS (μrad)	RESIDUALS (μA)
T 1	93.29	22	41	0.72
T 2	63.78	21	36	0.63
T 3	33.58	14	49	0.56
T 4	3.78	15	26	0.23
T 5	-26.27	3	10	0.07
T 6	-56.86	2	1	-0.23
T 7	-26.25	-15	-18	0.13
T 8	3.67	9	-8	0.41
T 9	34.16	-1	-13	-0.48
T10	63.85	-8	-26	-0.54
T11	93.56	-25	-46	-0.58
T12	33.48	-37	-53	-0.93
SHIFT:		-50	-102	-1.49

HYSTERESIS(p-p):

TEMP= 63.81	16	29	0.15
TEMP= 33.87	19	7	-0.05
TEMP= 3.72	17	12	0.84
TEMP=-26.26	-6	-6	0.40

SDC 1-91

SIZE	FSCM NO.	DWG NO.	REV
A	97896		
SCALE: NONE		SHEET	

050-2283-001 REV NEW

SDCF-1475

Figure 9.—Continued.

DWG NO. | SH | REV

SAMS CALIBRATION TEST DATA
X AXIS HG MODEL DATA SHEET

P/N 2 S/N 821 DATE 13-Aug-91 LOCAL g - 980.708 cm/sec²

TEMPERATURE (°C)		A10 (V/g)	A100 (V/g)	A1000 (V/g)	TEMP SENSOR (μA)
T 1	92.20	96.11752	960.9204	9506.571	369.490
T 2	63.92	95.74531	957.2482	9501.439	339.642
T 3	34.26	95.41526	954.0152	9527.755	309.364
T 4	4.73	95.14110	951.3787	9531.342	279.586
T 5	-24.91	94.92731	949.2589	9521.534	250.096
T 6	-55.40	94.79139	947.9272	9554.055	219.936
T 7	-24.91	94.92801	949.2697	9544.074	250.132
T 8	4.16	95.13806	951.3587	9538.840	279.341
T 9	33.98	95.41004	953.9897	9542.101	308.958
T10	63.26	95.73272	957.2601	9583.556	338.711
T11	92.11	96.10727	960.9093	9597.161	368.819
T12	33.19	95.39945	953.7158	9517.283	307.777

		COEFFICIENTS (@293μA)		COEFFICIENTS (@293μA)		COEFFICIENTS (@293μA)
CONSTANT:	F0=	95.25759	G0=	952.4604	H0=	9529.936
1st ORDER:	F1=	914.74E-05	G1=	891.78E-04	H1=	92.588E-03
2nd ORDER:	F2=	2993.1E-08	G2=	3335.6E-07	H2=	4513.1E-06
3rd ORDER:	F3=	-7245E-11	G3=	-5480E-10	H3=	-20712E-09
4th ORDER:	F4=	4942E-13	G4=	-766E-12	H4=	-8436E-11

TEMPERATURE (°C)		AMPLIFIER BIAS A10 (μg)	AMPLIFIER BIAS A100 (μg)	AMPLIFIER BIAS A1000 (μg)	TEMP SENSOR (μA)
T 1	92.20	-33	-34	-34	369.490
T 2	63.92	-31	-31	-31	339.642
T 3	34.26	-37	-38	-37	309.364
T 4	4.73	-54	-57	-56	279.586
T 5	-24.91	-92	-98	-98	250.096
T 6	-55.40	-162	-174	-173	219.936
T 7	-24.91	-95	-102	-101	250.132
T 8	4.16	-60	-63	-62	279.341
T 9	33.98	-43	-44	-44	308.958
T10	63.26	-35	-36	-35	338.711
T11	92.11	-35	-36	-36	368.819
T12	33.19	-40	-41	-41	307.777

050-2283-001 REV NEW

SIZE	FSCM NO.	DWG NO.	REV
A	97896		
SCALE: NONE		SHEET	

SDCF-1475

Figure 9.—Continued.

DWG NO. | SH | REV

SAMS CALIBRATION TEST DATA
Y AXIS HG MODEL DATA SHEET

P/N 2 S/N 821 DATE 13-Aug-91 LOCAL g - 980.703 cm/sec²

TEMPERATURE (°C)		A10 (V/g)	A100 (V/g)	A1000 (V/g)	TEMP SENSOR (μA)
T 1	92.84	104.26527	1082.1871	10057.033	369.673
T 2	64.15	103.83624	1078.1265	10200.212	339.895
T 3	34.24	103.43105	1074.0503	10215.418	309.339
T 4	4.56	103.08337	1070.3923	10212.462	279.364
T 5	-25.21	102.80185	1067.2977	10191.721	249.626
T 6	-55.83	102.60952	1065.3016	10224.388	219.175
T 7	-25.20	102.80242	1067.3776	10187.963	249.695
T 8	4.09	103.07989	1070.3639	10196.660	279.176
T 9	34.05	103.42603	1074.2139	10316.563	309.049
T10	63.57	103.82063	1078.3624	10343.574	339.011
T11	92.72	104.26667	1082.8823	10371.029	369.001
T12	33.20	103.40987	1073.8433	10338.857	307.746

	COEFFICIENTS (@293μA)		COEFFICIENTS (@293μA)		COEFFICIENTS (@293μA)	
CONSTANT:	F0=	103.23374	G0=	1072.0186	H0=	10251.163
1st ORDER:	F1=	1154.34E-05	G1=	1243.31E-04	H1=	1904.617E-03
2nd ORDER:	F2=	3098.7E-08	G2=	2904.2E-07	H2=	-10937.7E-06
3rd ORDER:	F3=	-10734E-11	G3=	-18553E-10	H3=	-360359E-09
4th ORDER:	F4=	5331E-13	G4=	4386E-12	H4=	106445E-11

TEMPERATURE (°C)		AMPLIFIER BIAS A10 (μg)	AMPLIFIER BIAS A100 (μg)	AMPLIFIER BIAS A1000 (μg)	TEMP SENSOR (μA)
T 1	92.84	-65	-195	-77	369.673
T 2	64.15	-55	-76	-60	339.895
T 3	34.24	-47	-67	-50	309.339
T 4	4.56	-45	-64	-47	279.364
T 5	-25.21	-50	-73	-53	249.626
T 6	-55.83	-65	-91	-70	219.175
T 7	-25.20	-52	-78	-56	249.695
T 8	4.09	-50	-71	-53	279.176
T 9	34.05	-52	-60	-55	309.049
T10	63.57	-57	-69	-61	339.011
T11	92.72	-67	-71	-71	369.001
T12	33.20	-46	-46	-48	307.746

SDC F81

050-2283-001 REV NEW

SIZE A	FSCM NO. 97896	DWG NO.	REV
SCALE: NONE		SHEET	

SDCF-1475

Figure 9.—Continued.

DWG NO.	SH	REV

SAMS CALIBRATION TEST DATA
Z AXIS HG MODEL DATA SHEET

P/N 2 S/N 821 DATE 13-Aug-91 LOCAL g - 980.705 cm/sec²

TEMPERATURE (°C)		A10 (V/g)	A100 (V/g)	A1000 (V/g)	TEMP SENSOR (μA)
T 1	93.15	97.23430	978.4330	10116.093	369.350
T 2	63.83	96.89578	974.8983	9918.659	339.922
T 3	33.52	96.59203	971.9385	9779.664	309.612
T 4	3.69	96.34086	969.5843	9719.509	279.819
T 5	-26.32	96.14976	967.6628	9698.650	250.286
T 6	-56.89	96.03984	966.2061	9609.191	220.172
T 7	-26.23	96.14946	967.8493	9751.484	250.357
T 8	3.53	96.33671	969.4454	9728.391	279.555
T 9	34.16	96.58655	971.7298	9657.921	309.204
T10	63.86	96.88479	974.5328	9737.226	338.966
T11	93.41	97.22552	977.5812	9760.843	368.665
T12	33.40	96.57708	971.3978	9603.178	307.873

		COEFFICIENTS (@293μA)		COEFFICIENTS (@293μA)		COEFFICIENTS (@293μA)
CONSTANT:	F0=	96.44502	G0=	970.4219	H0=	9655.234
1st ORDER:	F1=	836.95E-05	G1=	752.79E-04	H1=	-197.990E-03
2nd ORDER:	F2=	2906.9E-08	G2=	3608.6E-07	H2=	58362.0E-06
3rd ORDER:	F3=	-8778E-11	G3=	6293E-10	H3=	465555E-09
4th ORDER:	F4=	5794E-13	G4=	-14548E-12	H4=	-798805E-11

TEMPERATURE (°C)		AMPLIFIER BIAS A10 (μg)	AMPLIFIER BIAS A100 (μg)	AMPLIFIER BIAS A1000 (μg)	TEMP SENSOR (μA)
T 1	93.15	-75	-79	-79	369.350
T 2	63.83	-60	-55	-62	339.922
T 3	33.52	-48	-49	-49	309.612
T 4	3.69	-44	-49	-45	279.819
T 5	-26.32	-47	-59	-48	250.286
T 6	-56.89	-55	-71	-55	220.172
T 7	-26.23	-51	-68	-53	250.357
T 8	3.53	-51	-60	-53	279.555
T 9	34.16	-56	-64	-58	309.204
T10	63.86	-63	-74	-66	338.966
T11	93.41	-75	-84	-80	368.665
T12	33.40	-48	-49	-50	307.873

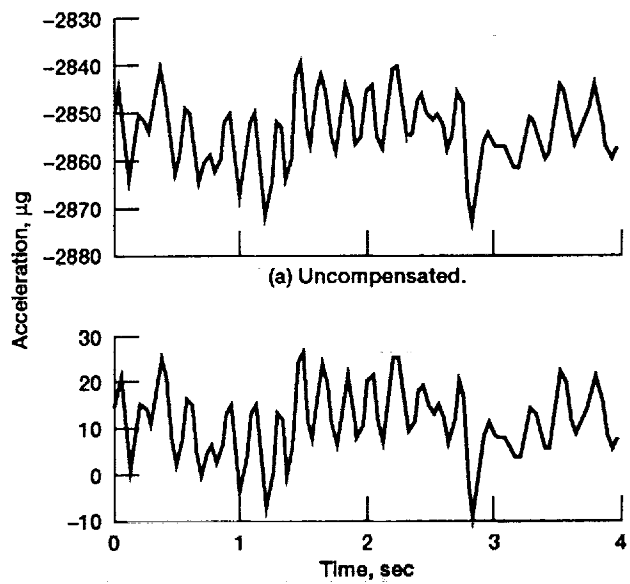
SDC F 91

050-2283-001 REV NEW

SIZE A	FSCM NO. 97896	DWG NO.	REV
SCALE: NONE		SHEET	

SDCF-1475

Figure 9.—Concluded.



(b) Compensated.

Figure 10.—Data from SLS-1 mission.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Space Acceleration Measurement System Triaxial
Sensor Head Error Budget

5. FUNDING NUMBERS
WU-694-03-OH

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER
E-6647

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TM-105300

11. SUPPLEMENTARY NOTES
John E. Thomas, NASA Lewis Research Center. Rex B. Peters, Sundstrand Data Control, Inc., 15001 N.E. 36th Street, Redmond, Washington 98073-9701 (work funded by NASA Contract NAS3-24816). Brian D. Finley, Sverdrup Technology, Inc., Lewis Research Center Group, 2001 Aerospace Parkway, Brook Park, Ohio 44142 (work funded by NASA Contract NAS3-25266). Responsible person, John E. Thomas, (216) 433-2658.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category 19

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***
The objective of the Space Acceleration Measurement System (SAMS) is to measure and record the microgravity environment for a given experiment aboard the Space Shuttle. To accomplish this, SAMS uses remote triaxial sensor heads (TSH) that can be mounted directly on or near an experiment. The errors of the TSH are reduced by calibrating it before and after each flight. The associated error budget for the calibration procedure is discussed herein.

14. SUBJECT TERMS
Acceleration; Microgravity applications; Accelerometers

15. NUMBER OF PAGES
28

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	